Signals and Circuits

ENGR 35500

Analog signals

Text books:
Ulaby, Fawwaz T., and Maharbiz, Michael M., *Circuits*, 2nd Edition, National Technology and Science Press, 2013.
Floyd, T. L., and Buchla, D. M., *Electroics Fundamentals: Circuits, Devices & Applications*, 8th Edition, Pearson, 2009.

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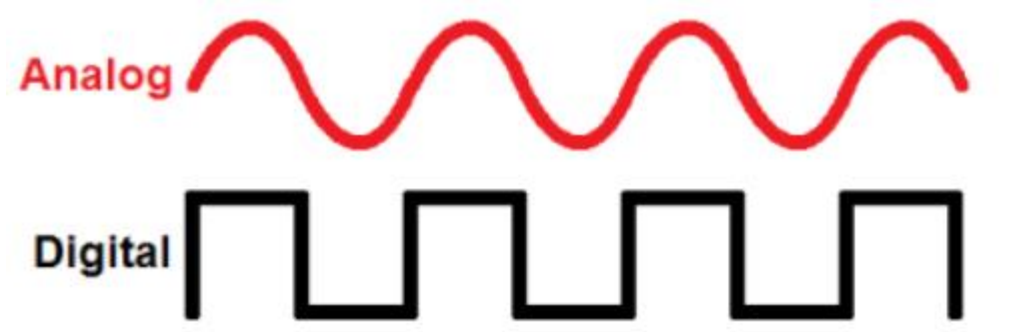
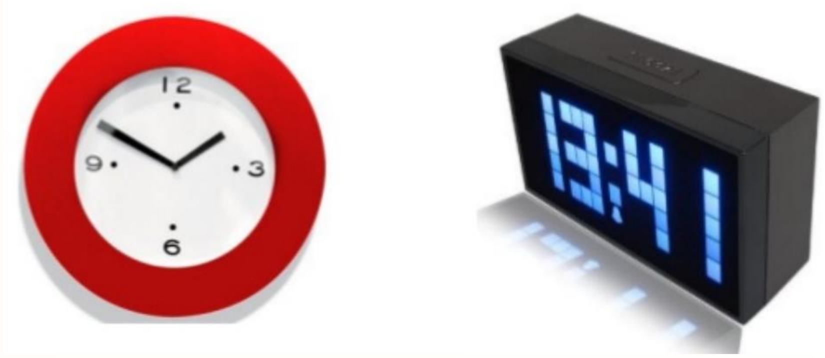
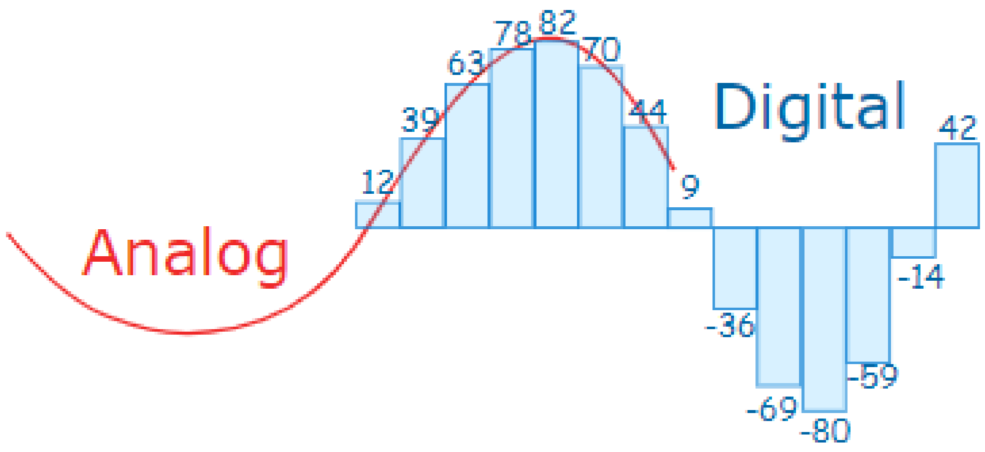
Analog versus Digital

- **Analog systems process time-varying signals that can take on any value across a continuous range of voltages (in electrical/electronics systems).**
- **Digital systems process time-varying signals that can take on only one of two discrete values of voltages (in electrical/electronics systems).**
  - Discrete values are called 1 and 0 (ON and OFF, HIGH and LOW, TRUE and FALSE, etc.)







Example:
An analog clock, whose hands move smoothly and continuously.
A digital clock, whose digits jump from one value to the next.

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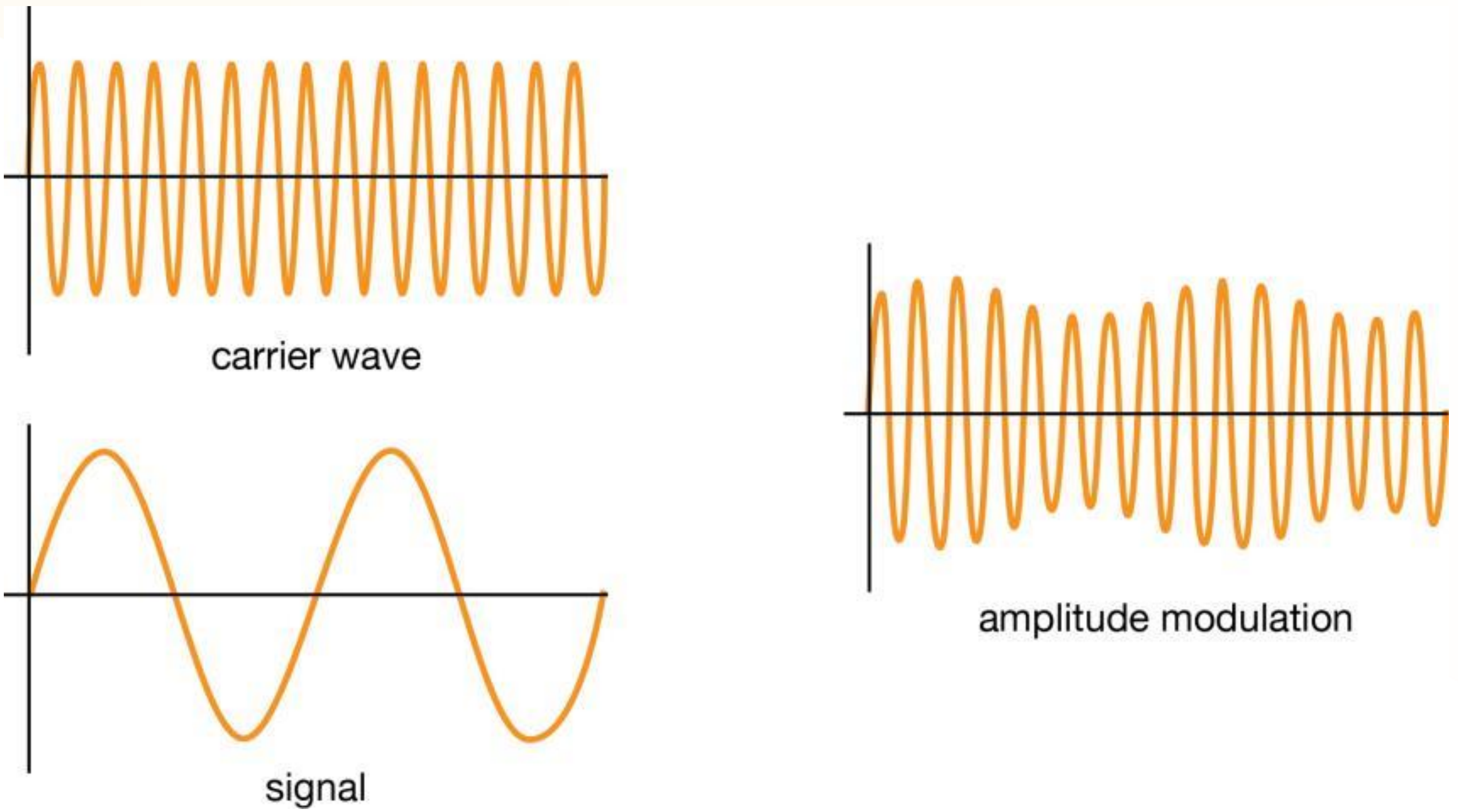
Analog Transmission

Analog to Analog

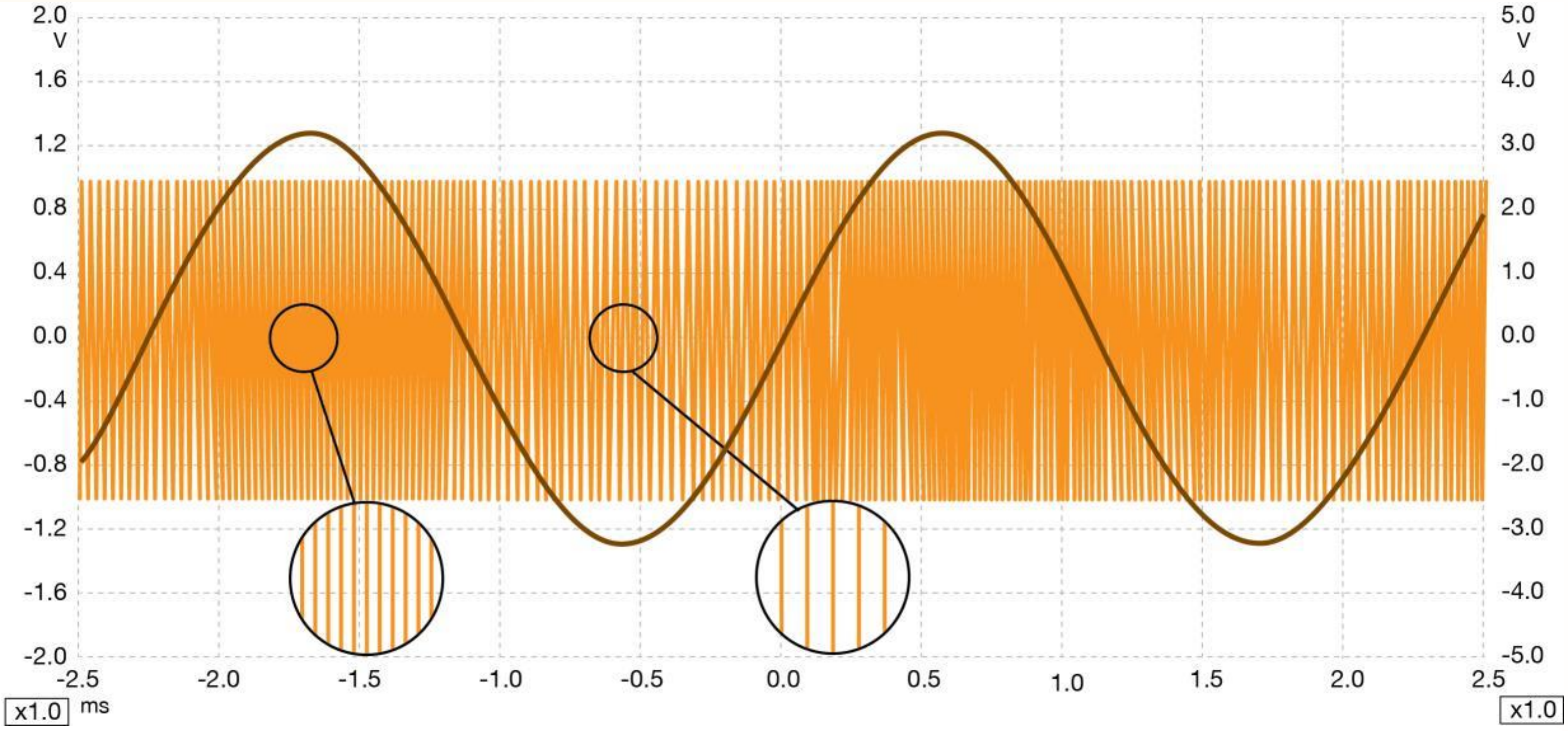
Amplitude modulation (AM)



Analog Transmission

Analog to Analog

Frequency modulation (FM)



Analog Transmission

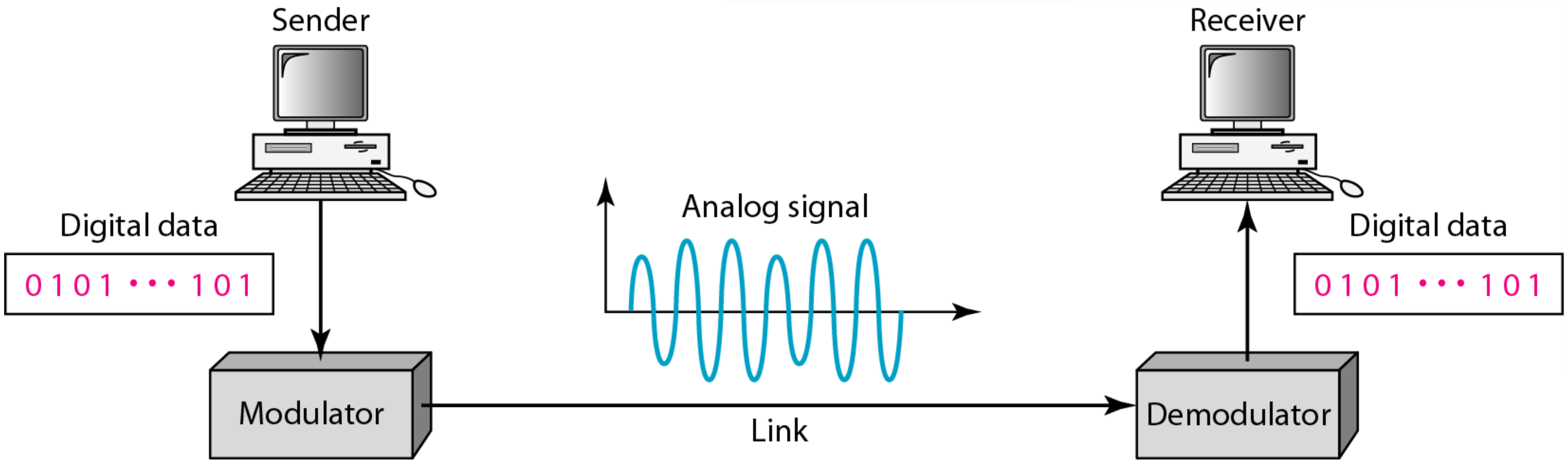
Digital to Analog Conversion

Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.

Digital data needs to be carried on an analog signal.

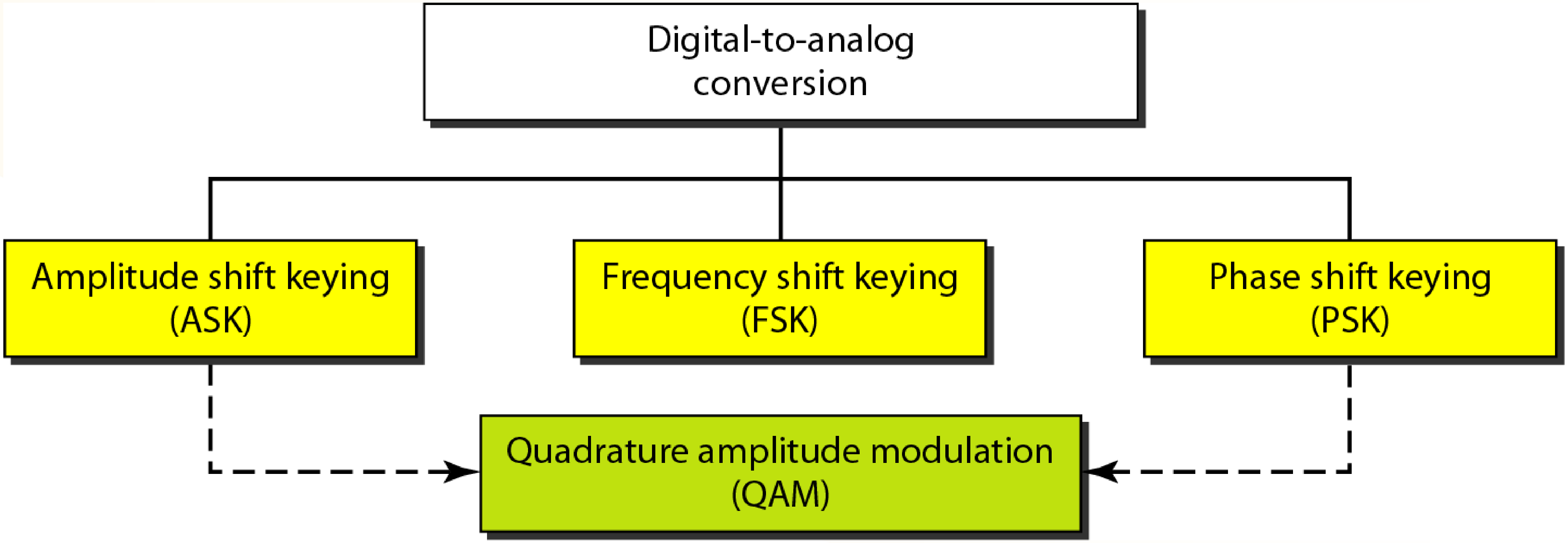
A carrier signal (frequency f_c) performs the function of transporting the digital data in an analog waveform.

The analog carrier signal is manipulated to uniquely identify the digital data being carried.



Analog Transmission

Digital to Analog Conversion



Bit rate, *N*, is the number of bits per second.

Baud rate, S, is the number of signal elements per second.

In the analog transmission of digital data, the baud rate is less than or equal to the bit rate.

$$S = N \times 1/r \text{ bauds}$$

Where r is the number of data bits per signal element.

Analog Transmission

Digital to Analog Conversion

An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution

In this case, r = 4, S = 1000, and N is unknown. We can find the value of N from

$$\boxed{S = N \times \frac{1}{r} \qquad \text{or} \qquad N = S \times r = 1000 \times 4 = 4000 \text{ bps}}$$

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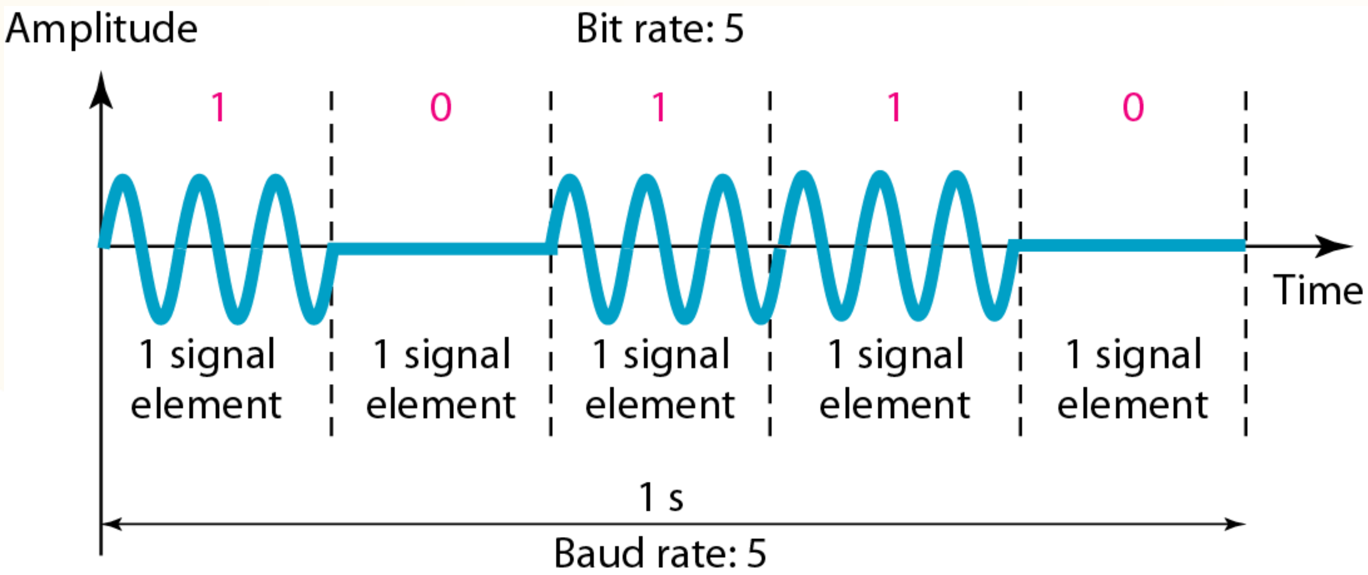
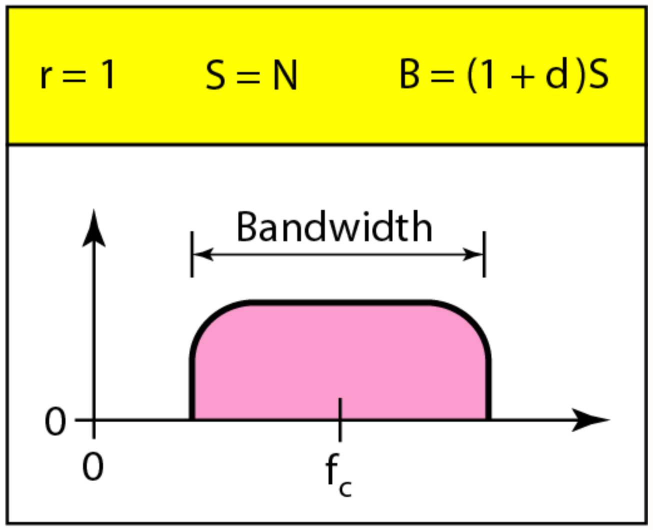
Binary amplitude shift keying (ASK)

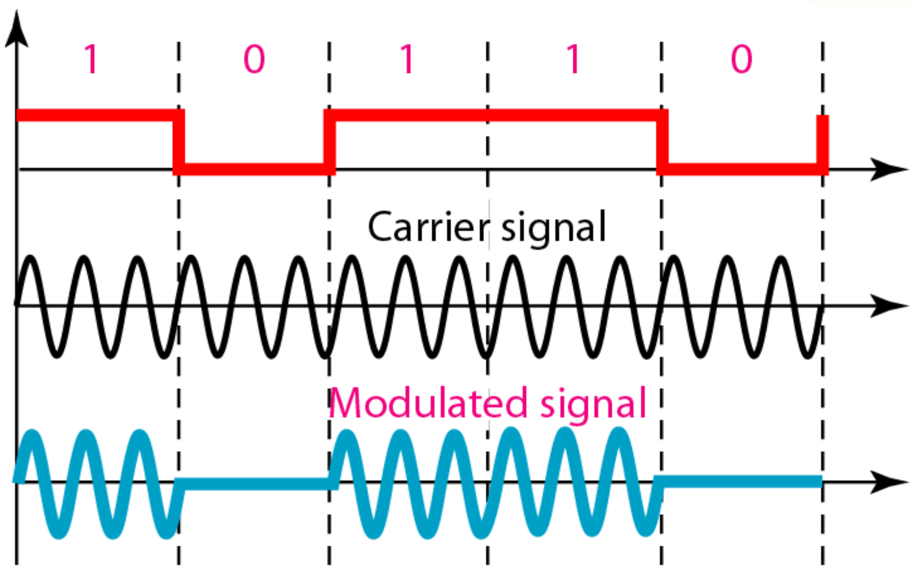


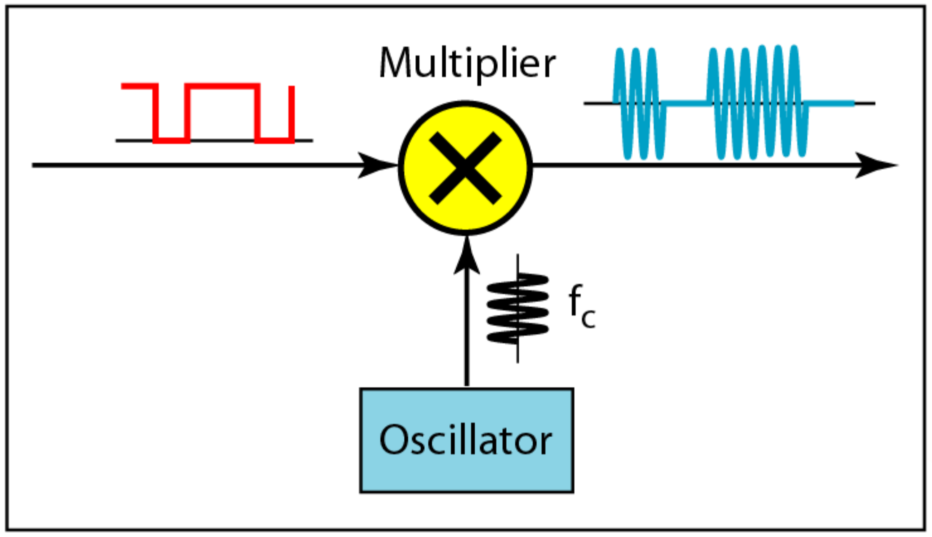


The bandwidth B of ASK is proportional to the signal rate S.

B = (1+d)S

“d” is due to modulation and filtering, lies between 0 and 1.





Binary amplitude shift keying (ASK)

NOTE: The bandwidth B of ASK is proportional to the signal rate S.

$B = (1+d)S$

"d" is due to modulation and filtering, lies between 0 and 1.

$S = N \times 1/r$ bauds

Where r is the number of data bits per signal element.

E.G

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz.

What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1,r=1?

Solution

The middle of the bandwidth is located at 250 kHz.

This means our carrier frequency can be at f_c = 250 kHz.

We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

$$\boxed{B = (1+d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \quad \longrightarrow \quad N = 50 \text{ kbps}}$$

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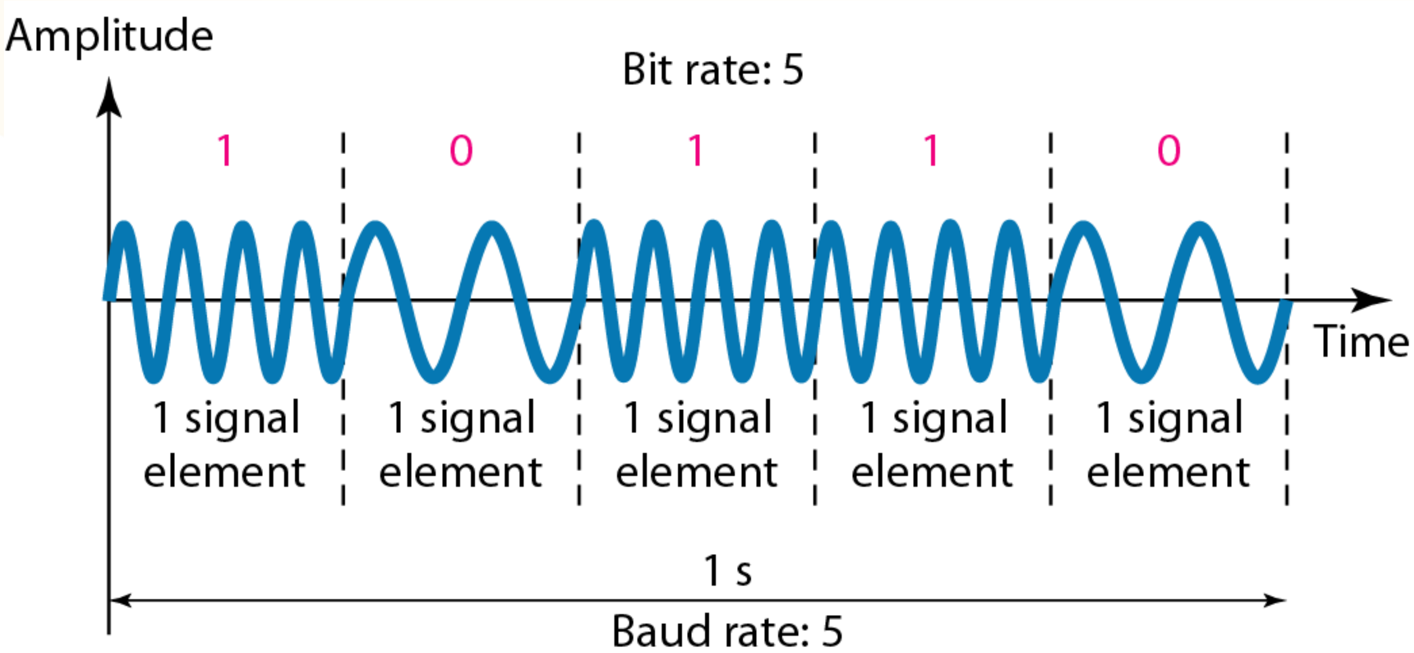
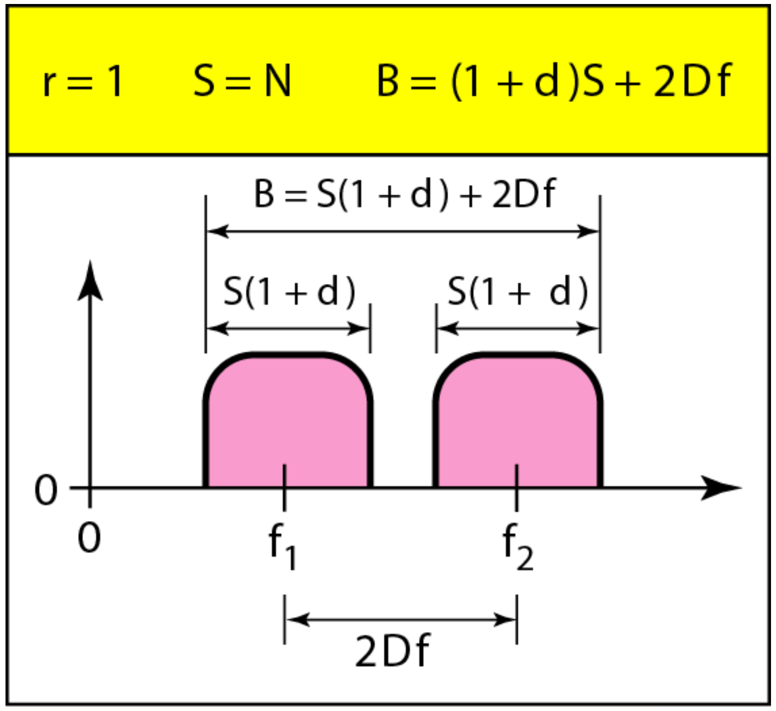
Binary frequency shift keying (FSK)



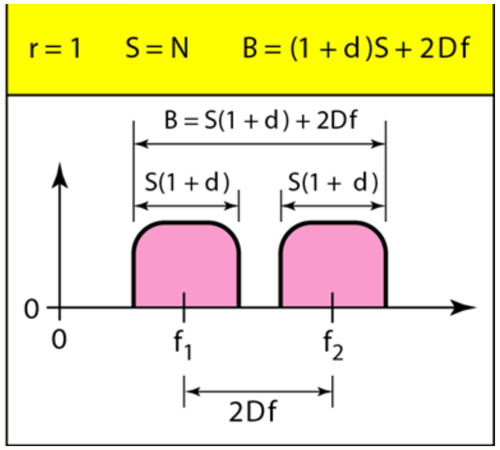


If the difference between the two frequencies (f_1 and f_2) is $2\Delta f$, then the required BW B will be:

$$B = (1+d)xS + 2\Delta f$$

Binary frequency shift keying (FSK)

NOTE: $B = (1+d) \times S + 2\Delta f$



We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

Solution

The midpoint of the band is at 250 kHz. We choose $2\Delta f$ to be 50 kHz; this means

$$\boxed{B = (1+d) \times S + 2\Delta f = 100 \Rightarrow 2S = 50 \text{ kHz} \quad S = 25 \text{ kbaud} \quad N = 25 \text{ kbps}}$$

$$f_1 = 225kHz, \quad f_2 = 275kHz$$

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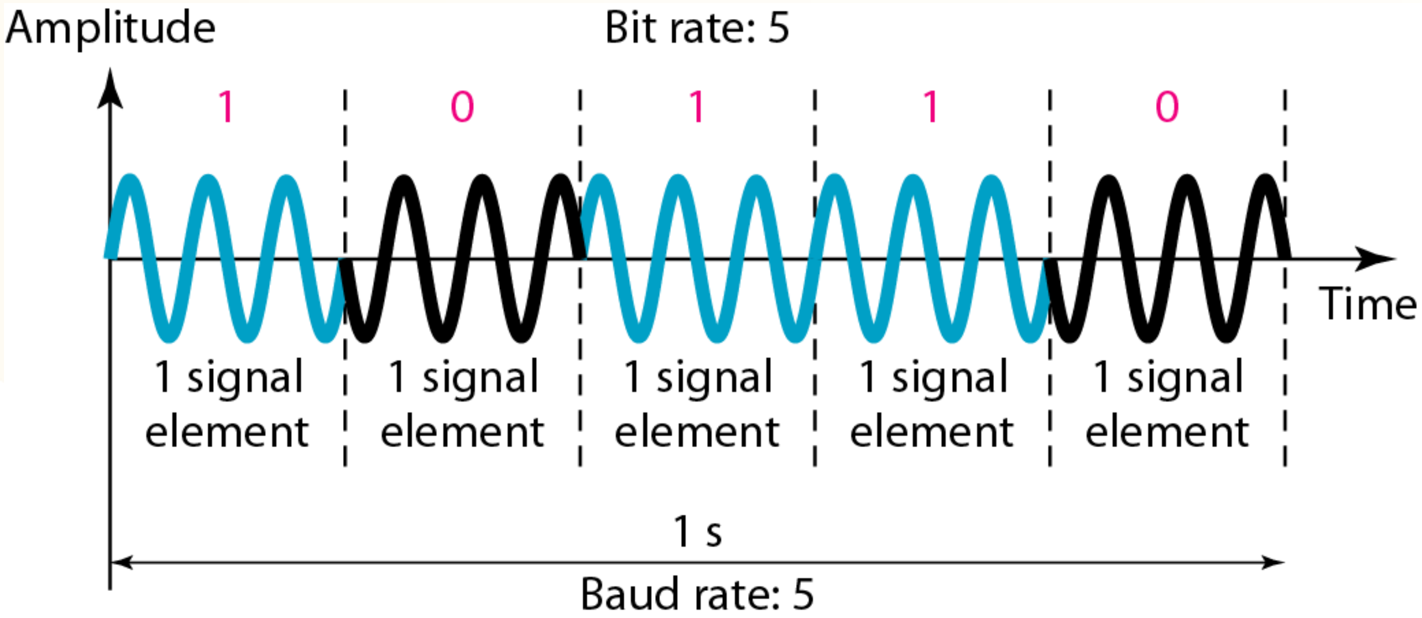
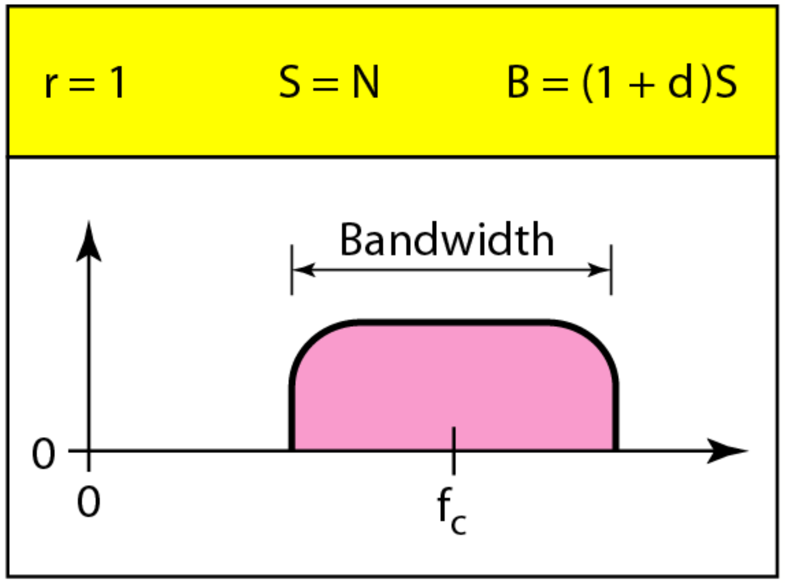
Binary phase shift keying (PSK)

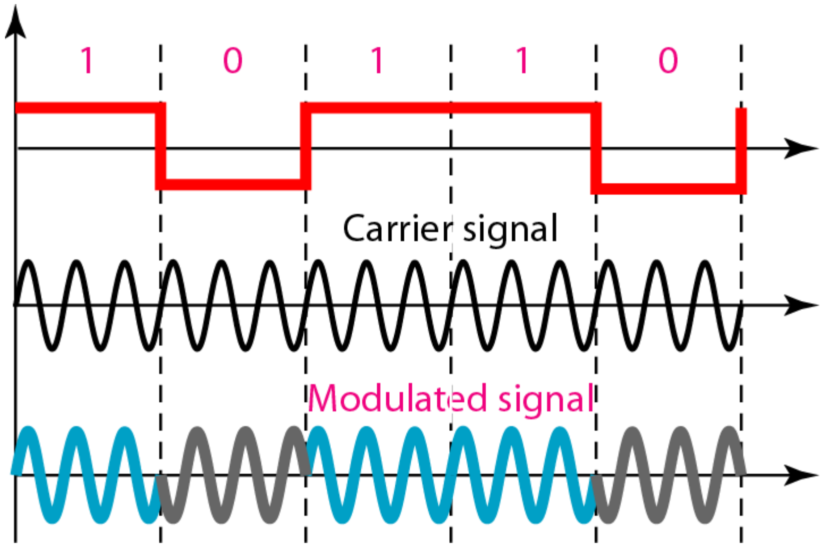


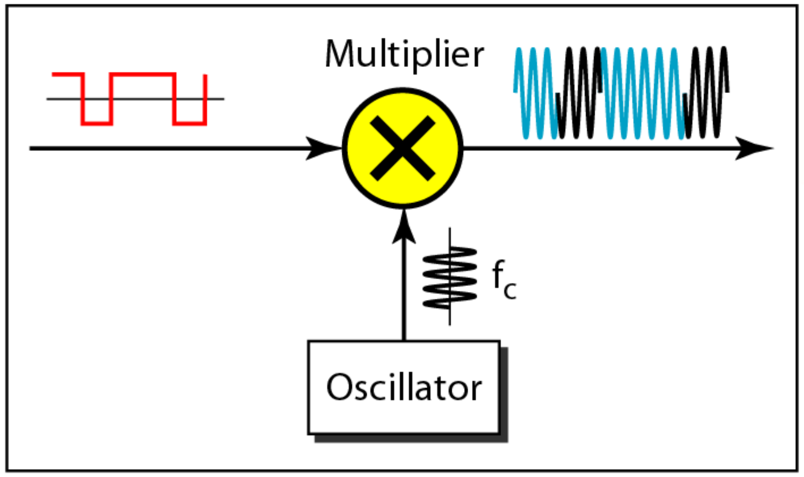


The bandwidth requirement, B is:

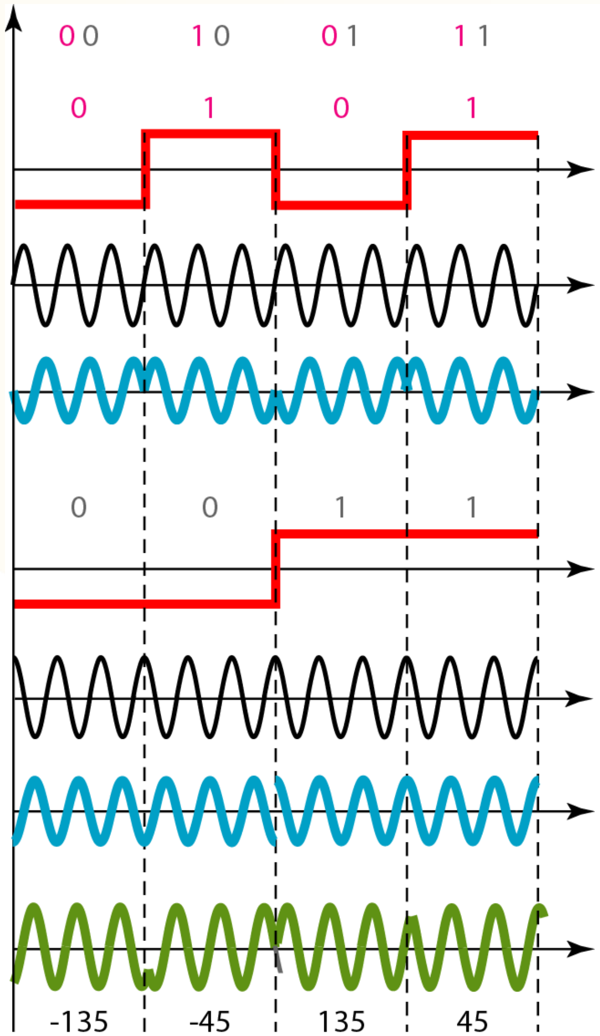
$$B = (1+d) \times S$$

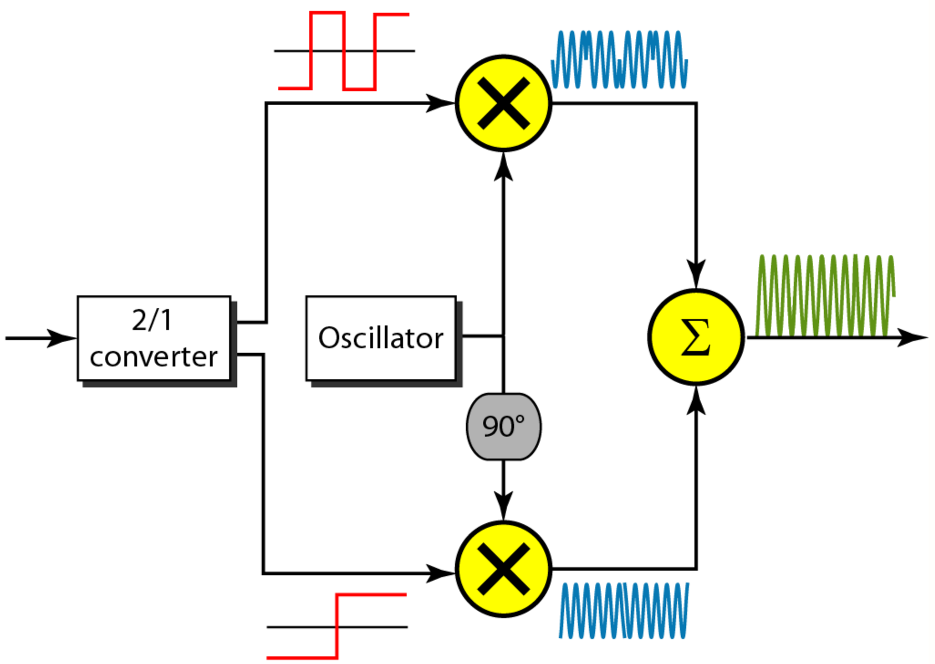
PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.





Binary quadrature phase shift keying (QPSK)





The bandwidth B of ASK is proportional to the signal rate S.

$$B = (1+d)S$$

"d" is due to modulation and filtering, lies between 0 and 1.

- To increase the bit rate, we can code 2 or more bits onto one signal element.
- In QPSK, we parallelize the bit stream so that every two incoming bits are split up and PSK a carrier frequency. One carrier frequency is phase shifted 90° from the other in quadrature.
- The two PSKed signals are then added to produce one of 4 signal elements. L = 4 here.

Binary quadrature phase shift keying (QPSK)

NOTE: $S = N \times 1/r$ bauds $B = (1+d)S$

Where r is the number of data bits per signal element.

Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.

Solution

For QPSK, 2 bits is carried by one signal element. This means that r = 2. So the signal rate (baud rate) is S = N × (1/r) = 6 Mbaud. With a value of d = 0, we have B = S = 6 MHz.

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